Final report for
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During the funding period, this grant partially supported the PI (Zhihong Lin), two postdoctoral researchers (Yasutaro Nishimura and Igor Holod), two graduate students (Hongpeng Qu and Peter Porazik), and undergraduate (Jason Siu) working on a summer research project.

This grant also contributed to the construction of a local computer cluster, which has been used for both research and education activities associated with this project. The PI has been promoted to the rank of associate professor with tenure at the Department of Physics and Astronomy of the UCI, and one of the graduate students (Qu) has nearly completed a Ph. D thesis project.

The research results have been published in several refereed journal papers and proceedings of IAEA fusion and SciDAC conferences, and have been widely disseminated via oral and poster presentations at many national and international conferences. The numerical methods and physics insights developed in this project have contributed to the GTC project in the DOE SciDAC Center for Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas (GPS), and to the Center for Plasma Edge Simulation (CPES), one of the SciDAC fusion simulation prototype centers. The electromagnetic hybrid electron model has been implemented in the GTC code by the PI's research associate, Dr. Yas Nishimura, of UCI. This new capability enables GTC simulation of electromagnetic turbulence and Alfven turbulence driven by the α-particles in the burning plasmas such as the International Thermonuclear Experimental Reactor (ITER).

Theory and simulation of compressional magnetohydrodynamic modes in high-β plasmas -- The finite Larmor radius (FLR) effects play an important role in determining the threshold and the growth rate of the mirror instability. In this study, a general dispersion relation of the mirror mode with FLR effects is derived by using gyrokinetic theory. It shows that both the FLR effects and the coupling to the slow sound wave are stabilizing. A gyrokinetic particle simulation code has been developed for simulation of compressible magnetic turbulence driven by the mirror instability. Results of the linear simulation of mirror mode agree well with the analytic dispersion relation. Results of the linear simulation of mirror mode agree well with the analytic dispersion relation. Nonlinear simulations find that a coherent mode saturates via a phase space trapping.

Global simulations of electromagnetic turbulence in tokamak plasmas-- Electromagnetic gyrokinetic simulation in toroidal geometry using GTC code is developed based on a fluid-kinetic hybrid electron model. The Alfven wave propagation in a fully global gyrokinetic particle simulation is investigated. In the long-wavelength magnetohydrodynamic limit, shear Alfven wave oscillations, continuum damping, and the appearance of the frequency gap in toroidal geometries are demonstrated. Wave propagation across the magnetic field (kinetic Alfven wave) is examined by comparing the simulation results with the theoretical dispersion relation. Furthermore, finite-beta stabilization of the ion temperature gradient mode and the onset of the kinetic ballooning mode are demonstrated.

Statistical properties and transport of particle noise in Gyrokinetic simulations -- The problem of discrete particle noise has been studied based on direct fluctuation measurement from gyrokinetic particle-in-cell simulations of stable plasmas. From the statistical analysis of electrostatic potential time evolution, the space-time correlation function has been measured. Fluctuation spectra have been constructed and analyzed in detail. Noise-driven transport is calculated using the quasilinear expression for the diffusion coefficient and the obtained noise spectrum. The theoretical value of electron heat conductivity shows good agreement with that measured in the simulation. It has been shown that for the realistic parameters in actual turbulence simulations, the noise-driven transport depends linearly on the entropy of the system. This study makes it possible to estimate and subtract the noise contribution to the total transport during turbulence simulations.

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